Time Scale Invariance of the Low-Cloud Albedo Feedback in CMIP3

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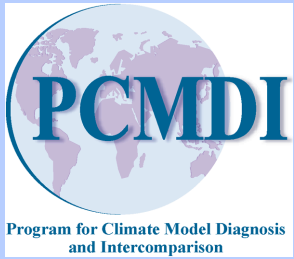


Background

- Cloud feedbacks are a large source of variability in model projections of future climate
- Previous work using satellite (*Tselioudis et al.*, 1992) and in-situ (*Somerville and Remer*, 1984) observations of clouds suggest clouds in the extratropics get brighter as they warm (adiabatic increase in cloud liquid water)
- However, there is also indication that optical thickness for clouds in the tropics and subtropics decrease as they warm (*Tselioudis et al.*, 1994; *Chang and Coakley*, 2007)

Big Questions

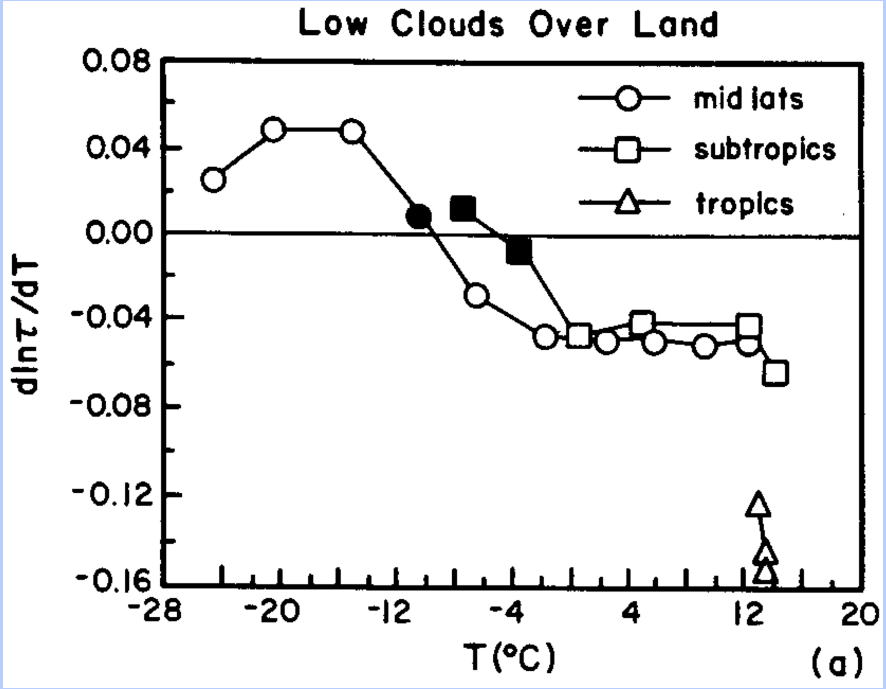
- Can climate models replicate the observed relationships between optical thickness and temperature?
- Can models help us understand how and why clouds change as the climate warms?
- Can information on the way cloud feedbacks operate in our current climate provide information on how they will affect climate change?

CMIP Data

- Daily-mean output from 7 models for control run and 2xCO_2 run (5 years each)
- Cloud optical thickness from ISCCP simulator (clisccp)
- Derive cloud-top temperature from atmospheric temperature on model levels
- Analyze all clouds below 680mb, with clear-sky above

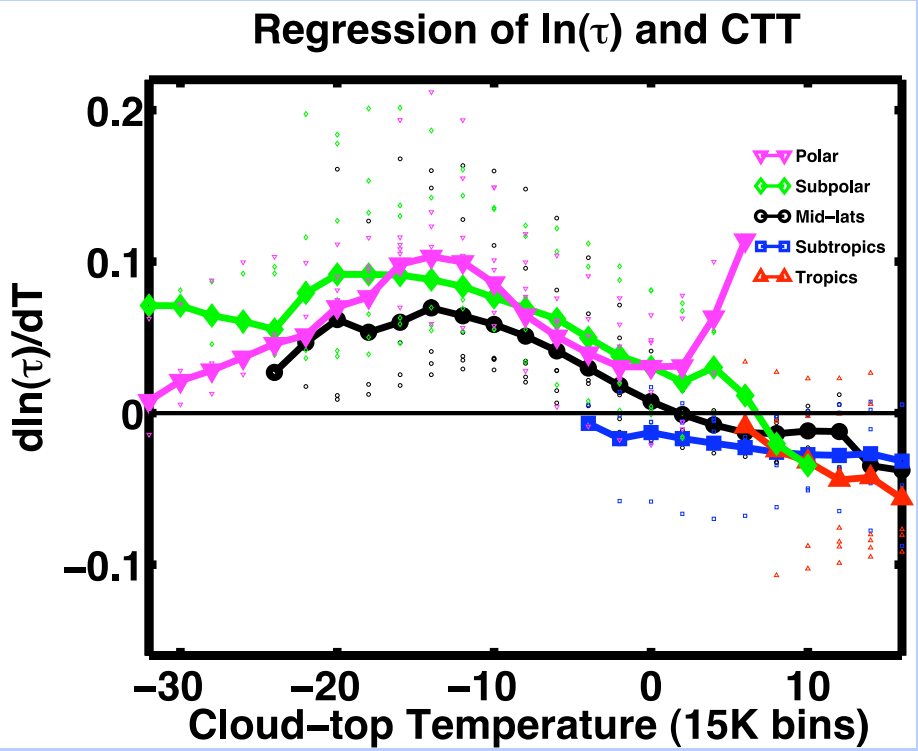
Previous Research

- The relationship between cloud-top temperature and cloud optical thickness for low clouds, sorted in 15K bins of cloud-top temperature (from *Tselioudis et al.*, 1992)



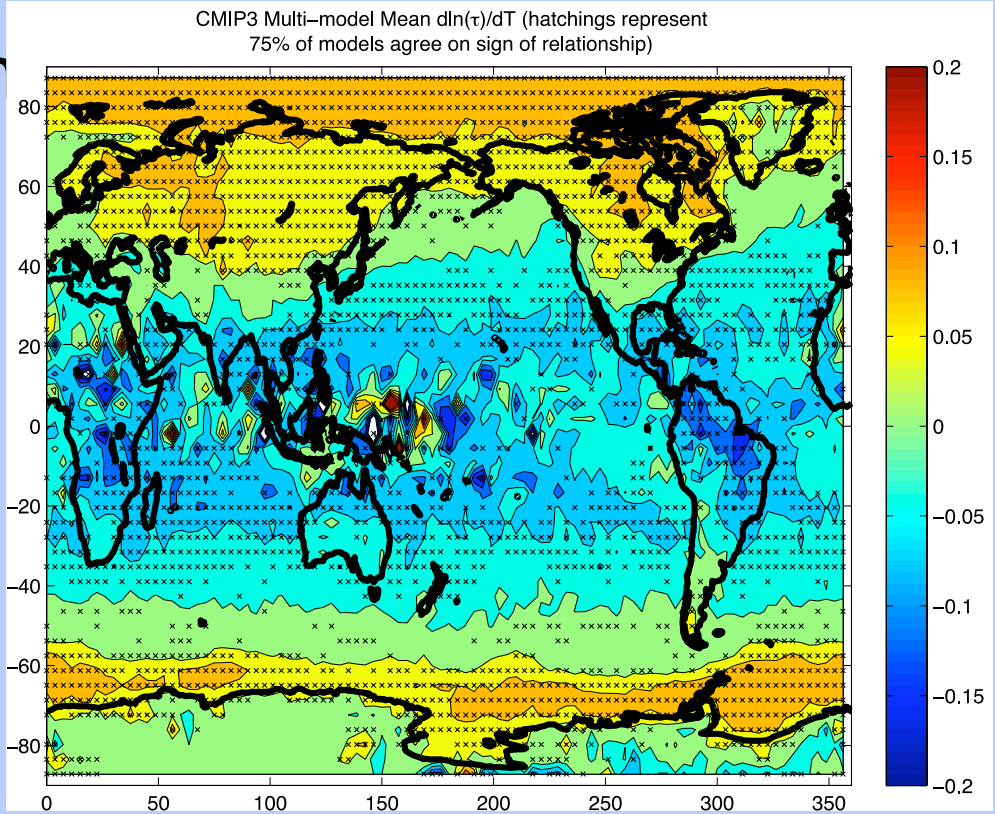
Optical Depth Feedback in CMIP3

- The relationship between optical depth and cloud-top temperature for low clouds in 7 models (individual dots) and the multi-model average (solid line) in the control climate



Optical Depth Feedback

- Now, we calculate th
  regression for each
  location; positive
  relation in
  extratropics with
  negative in tropics



Source of Feedback

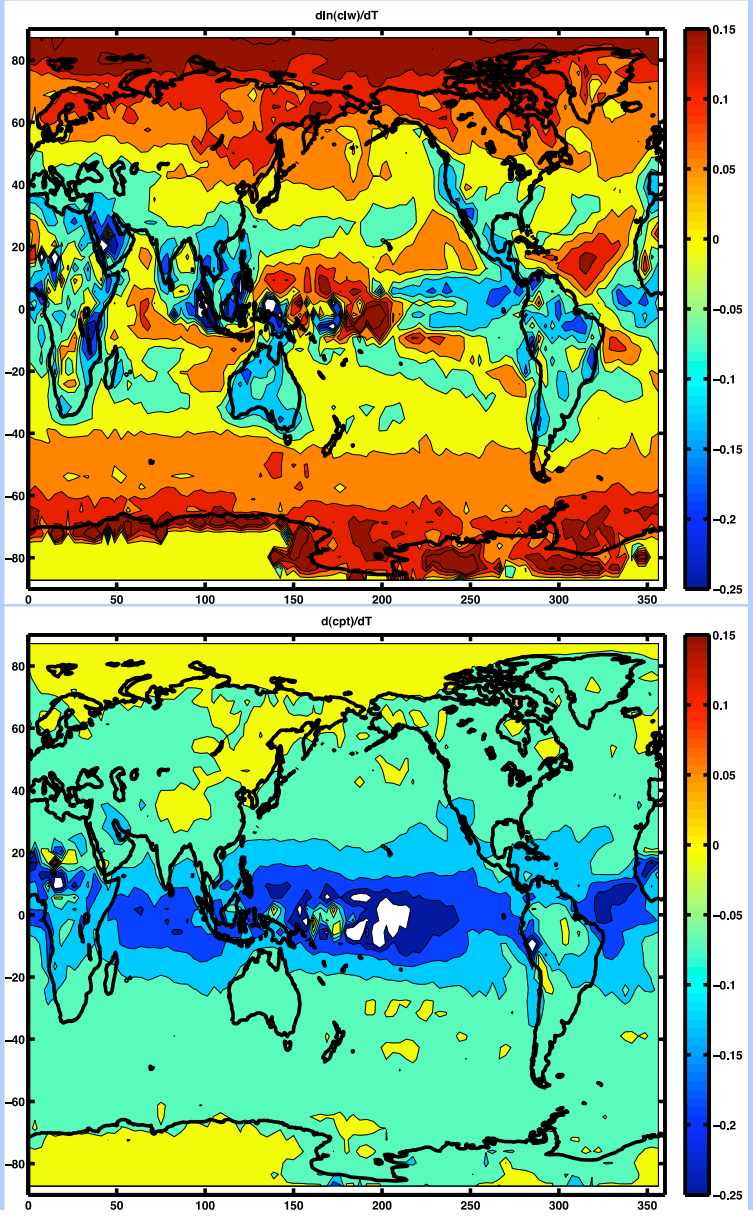
- By using the following equation

$$\tau = \frac{3}{2}\frac{LWC^{*}\,\Delta z}{r_e}$$

we can derive what portion of the feedback comes from changes in liquid water content and cloud physical thickness (r_e not an output from any model)

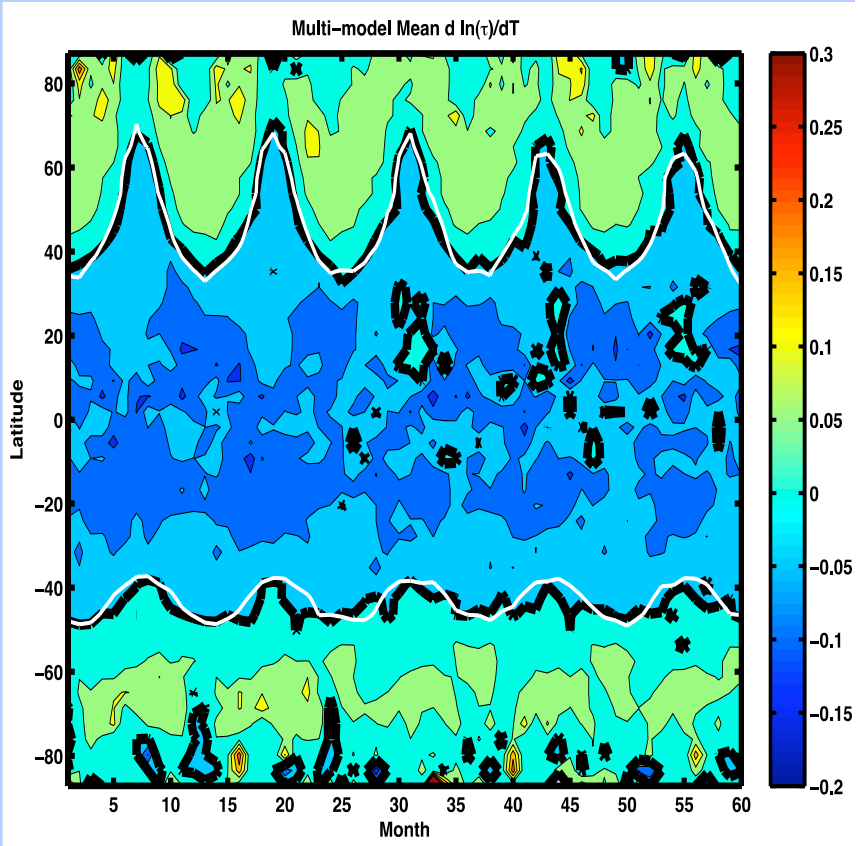
Source of Feedback

- Change in cloud liquid water
- Change in cloud physical thickness



Temperature Dependence of Feedback

- What is the significance of the switch from negative to positive optical depth feedback
- Local dln(tau)/dT as a function of latitude and time; solid dark line is zero feedback, white line is cloud temperature contour of 0 degrees C

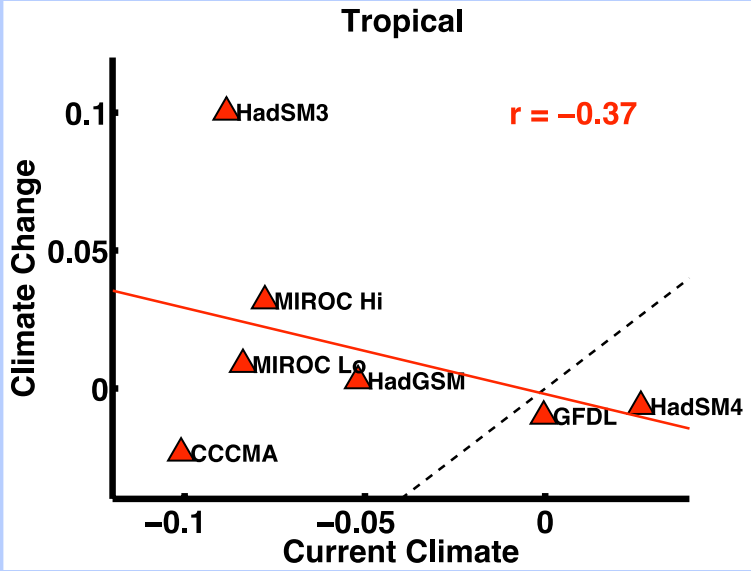


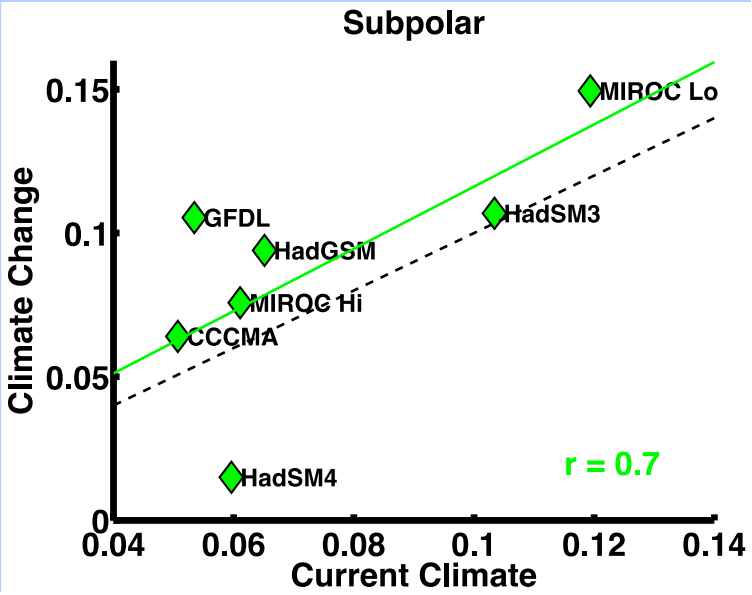
Timescale Invariance of Feedback

- Do feedbacks in the control climate compare to climate change feedbacks?
- Take difference in optical depth between $2xCO_2$ and control climate for each grid box, then divide by cloud-top temperature change
- Next we compare the feedback calculated for the control climate to that for climate change, separately for each region

Time Invariance of Feedback

- Tropics (0-15°)
- Sub-polar (55-70°)





Conclusions

- The optical depth feedback for low clouds in models is similar to that from satellite and in situ observations
- Feedback is driven by different mechanisms in different regions; increase in cloud liquid in the extra tropics, while changes in physical thickness contribute in the tropics
- Control climate feedback is good proxy for climate change response in models only for some regions

Thank You!

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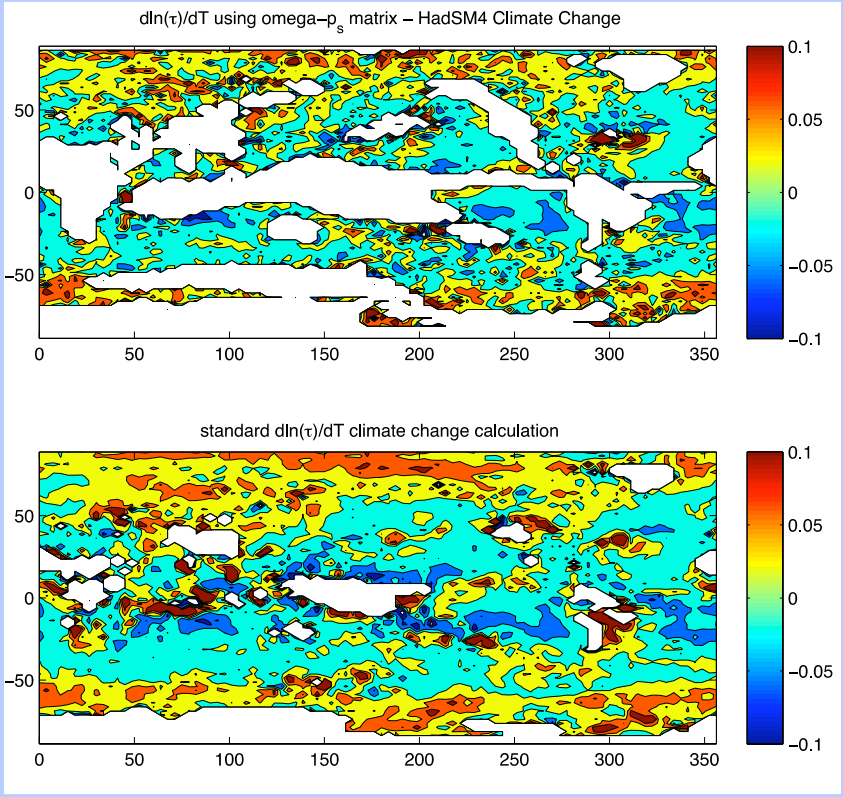
Dynamical Partitioning

- For each grid box, we calculate joint histograms of 500-mb vertical velocity and surface pressure
- The mean τ and cloud-top temperature is calculated for each bin in the joint histogram, for the control and $2xCO_2$ runs
- The change in optical depth is then calculated for each histogram bin; a mean for the grid box is a weighted mean of all the bins

Climate Change dln(τ)/dT



- Calculation of dln(τ)/dT using partitioning of vertical velocity and surface pressure
- Naïve calculation of dln(τ)/dT using change in optical depth from control to 2xCO_2 climate